A Hollow Fiber-based Micro-tubular SOFC for Efficient Current Collection from the Inner Electrode

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Solid oxide fuel cells (SOFCs) are widely accepted as one of the most promising next-generation energy conversion devices due to their high efficiency, fuel flexibility, and high exergy ratio of the byproduct heat. Out of two basic designs of SOFC, i.e. planar and tubular, tubular ones are known for technological maturity, stable performance over long runs, and less stringent requirements for high-temperature sealing between fuel and oxidant streams. However, a serious drawback of tubular SOFCs is their low volumetric power density. To address this issue, recently small-size tubular SOFCs, called micro-tubular SOFCs, have been introduced [1]. Against the typical diameter of about 25 mm for their conventional counterparts, micro-tubular SOFCs have a diameter in the range of 1–5 mm, thereby providing a larger surface area to volume ratio so as to achieve a higher power density. In addition, micro-tubular SOFCs have been reported to offer a shorter start-up time and better resistance to thermal degradation on cycling [1]. In spite of several favorable characteristics, current collection from the inner electrode (i.e. bore side) of the micro-tubular SOFC has been identified as a major problem. Due to the contact of current collecting elements only at the ends of the inner electrode, there is a considerable ohmic loss in current collection and this loss goes on increasing with the length of SOFC [2, 3]. To deal with this issue, the present research proposes a novel design of the micro-tubular SOFC based on ceramic hollow fibers (HFs).

A schematic of the proposed design of the micro-tubular SOFC is illustrated in Figure 1. The design consists of a porous ceramic HF as the structural support above which several functional layers are deposited. The use of the porous HF as the support member makes it possible to coat a thin porous layer of metallic current collector for collecting current from the entire surface of the inner electrode. The coated layer of the current collecting material essentially works as a meshed collector which has been found to be the best option for current collection from both anode and cathode [4]. Additionally, the proposed design offers the advantage of facile manufacturing since simple thin-film coating techniques such as dip-coating can be employed to fabricate the layers of electrodes and electrolyte.

For a proof-of-the-concept study of the proposed design, porous tubes of alumina with a porosity value of 30% were selected as the support of the cell. The tubes had inner and outer diameters of 2 and 6 mm, respectively. Considering its thermal and chemical compatibility with the most widely used Ni-YSZ (yttria-stabilized zirconia) anode, nickel was chosen as the current collecting material. The deposition of nickel on the alumina tubes requires precise control because the nickel layer should be porous enough not to hinder the gaseous diffusion while there should be good connectivity between the nickel particles. Therefore, preliminary experiments were conducted for an electroless deposition of nickel on the alumina tubes. SEM micrographs of the surface of an alumina tube before and after the electroless deposition of nickel at 70 °C for 4 minutes are shown in Figure 2(a) and (b), respectively. The nickel was observed to be deposited well without any sacrifice in the porosity of the alumina tube. The next step of the fabrication process will be the deposition of porous and dense layers of electrodes and electrolyte, respectively. The complete fabrication and electrochemical characterization of the proposed micro-tubular SOFC are currently in progress.

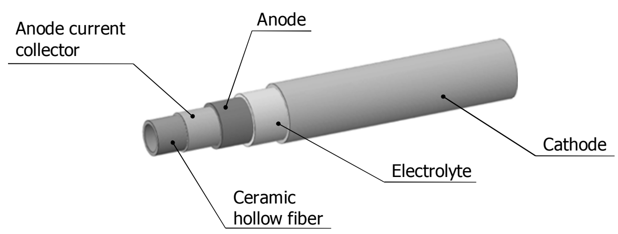
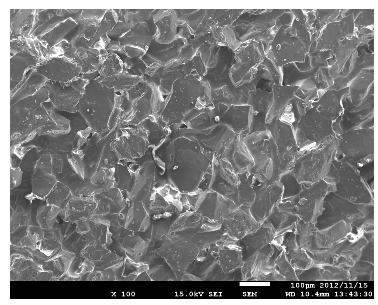
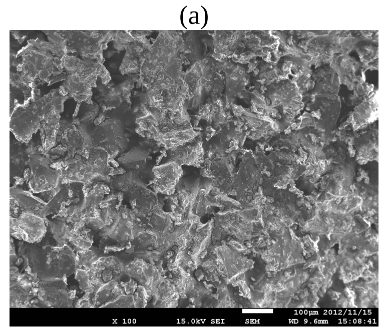


Figure 1 HF-based novel design of micro-tubular SOFC.



(a)



(b)

Figure 2 SEM micrographs: (a) porous surface of an alumina tube; (b) a thin layer of nickel deposited on the surface of the alumina tube.

References

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